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THERE HAS BEEN INCREASING SPECULATION over the past several years that rapid advances in information technologies will enable tremendous leaps in future combat systems performance. Perhaps the most significant development is the prospect that new high-data-rate communications satellites will soon offer worldwide wireless information transmission capacities that can fully exploit the tremendous speed of modern information processing.[1] If achieved, this "bandwidth on demand" will allow virtually unlimited amounts of information to be exchanged in real time between positions anywhere on the globe.

Since it was first introduced just over a century ago, wireless radio has been used by militaries to link together geographically scattered platforms for mutual coordination and support. Given limitations on data-transmission capacity, range, and reliability, military operations have been characterized by largely autonomous multipurpose platforms or units operating in relative independence of one another. However, the prospect of unlimited bandwidth is now stimulating efforts aimed at creating a fully integrated operational network of widely dispersed sensors, weapons, and command entities that will effectively function as a single combat unit—the so-called "system of systems."[2] This is a central goal for future U.S. military forces, articulated in the 1997 Quadrennial Defense Review, the Joint Chiefs of Staff "Joint Vision 2010," and the individual service visions.[3] Some predict that creation of this system of systems will lead

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in the relatively near term to transition from military operations based on the coordinated actions of individual platforms to an approach centered on the network itself—what is being called "network-centric warfare."[4]

The full integration of battlefield systems within a common information network appears to hold out the prospect of three significant advances. First, networking of long-range sensors and weapons allows for the simultaneous massing of dispersed fires on common targets—thus achieving greater combat effectiveness per unit of force. Second, geographic dispersal enabled by the network improves own-force protection by denying lucrative targets to the enemy's long-range strike systems. Third and perhaps most importantly, full networking of information between units would appear to allow a tremendous increase in the tempo of operations, reducing the delay between observation and action on the battlefield. Some proponents foresee a transition to a wholly new measure of combat effectiveness whereby "speed of command" replaces attrition of enemy forces as the battlefield goal.[5] The idea is that a higher relative speed of operations should make possible preemptive actions that effectively forestall an enemy commander's options. Denied an ability to take the initiative without unacceptable risk of being destroyed, the enemy is theoretically paralyzed. Some maintain that the mere prospect of such command paralysis may deter aggression from the outset.[6]

The pace of information systems development suggests that the real challenge ahead, however, is not so much technological as organizational—that is, how best to organize people around these systems so as to exploit fully their capabilities. There has been considerable speculation about future military-technical possibilities, but there has been remarkably little discussion about the prospect of future concomitant organizational change within the military services. Historians of military innovation would not be surprised. All military organizations are self-contained societies with distinct cultural characteristics, including unique customs, rituals, social hierarchies, and narrowly defined criteria for membership and promotion. In his now-classic study of innovation in the U.S. Navy, Elting Morison observed that the introduction of a new technology into the military places in jeopardy—and indeed may even destroy—many long-standing "mores and structures" of the established military society.[7] He concluded that this *cultural* impact of organizational change has been the primary impediment to the exploitation of new technologies, often delaying by a generation or more even improvements commonly acknowledged to be in the best interest of the service. Potential cultural resistance to the exploitation of emerging information technologies is not yet clear, but the problems experienced by the U.S. Navy in its effort to incorporate wireless radio into fleet operations a century ago offers some insight into the types of challenges that lie ahead for all of the military services.[8]

The Wireless Revolution

The military utility of wireless was readily apparent to most of the world's navies soon after Guglielmo Marconi first demonstrated radio communication between ship and shore in 1897; wireless radio systems were rapidly acquired and installed on the major warships of the principal fleets of the world. The subsequent impact of wireless on naval operations is hard to overstate. Since sensors and communications had been limited to relatively short line-of-sight distances, formations of ships had little prospect of encountering enemy units while having sufficient firepower for a successful engagement unless they hovered close to ports or coastal chokepoints. Thus, prior to 1900 only one naval battle is known to have been fought far beyond sight of land.[9] With the arrival of wireless, dedicated platforms such as fast scout cruisers and aircraft could search out to extended ranges, and long-range communications could be used to effect a geographic massing of the battle fleet against the enemy. Not only did this horizontal network of sensors, weapons, and command authorities greatly expand the potential battle space, but fleets with superior information relative to an adversary could exercise much greater control than previously over the time and place of an engagement—multiplying their effectiveness by massing mobile units rapidly where and when desired.

The British navy was among the world's leaders in exploiting wireless, introducing radio for fleet scouting in maneuvers off the British Isles in 1899. In that same year the U.S. Navy conducted its first successful tests of wireless afloat, prompting the Bureau of Equipment to press for the installation of wireless sets in all major warships and shore headquarters. Although wireless equipment was made readily available to U.S. warships, however, it saw little or no operational use for nearly two decades. There was no concerted effort by afloat units to exploit it, and the equipment was generally ignored by at-sea commanders. Radio discipline was practically nonexistent, and traffic was dominated by operator talk and personal messages. Since no attempt was made to limit output power over short distances, interference on the Navy's single frequency for wireless traffic was a persistent problem.[10] As late as 1912 the U.S. Navy had no standardized procedures for fleet radio communications. With little fleet support, wireless equipment seldom received adequate attention for installation, operations, maintenance, or training. For the most part, radio was relegated to enlisted personnel and little noticed by shipboard officers.

To be sure, there were many problems to be overcome in the early years of wireless. The prospects of jamming and signal interception were thought by some to make radio of questionable utility during wartime;[11] in addition, technical problems persisted with the many new types of equipment being procured. But as Susan Douglas concludes in her study of the Navy's adoption

of wireless radio, these factors appear to have had less to do with the failure to exploit wireless at sea than did the organizational and cultural changes that arose with efforts to incorporate long-range communications into fleet operations.[12] For the line officer afloat, the operational advantages were outweighed by the reduction in individual authority and prerogative likely to result from instant contact with superiors—especially those ashore. Prior to wireless commanding officers had exercised virtually unlimited independence once beyond visual or telegraphic contact with senior commanders. In view of the service's tradition of independent operations (the U.S. Navy did not institute a permanent fleet organization until 1907), the degree of centralized control that wireless offered threatened to change radically the criteria by which the profession and society of the line officer—the "corps of command"—defined itself.[13] One anti-wireless writer of the period expressed concern that the "independent action of fleet commanders in war" would be "interfered with by those far from the scene"; he viewed with great concern the prospect of "a fleet commander in a few years directing a battle at sea with his ear attached to a wireless telephone and repeating with megaphone the order buzzed into his ears from some departmental head hundreds of miles away."[14]

Radio was seen to deny critical initiative in combat situations. Commanders would no longer be able to exercise Nelson's prerogative of "looking at an unwelcome signal through his blind eye," or to replicate Commodore Dewey's decision to "cut cable communication with the outside world and 'go it alone'" into Manila Bay.[15] This view was commonly shared throughout the afloat hierarchy, where even senior line officers generally acquiesced when subordinate ship captains "often simply shut down their radios at sea so as to avoid receiving undesirable orders."[16]

The organizational changes necessary to exploit wireless were eventually adopted by the U.S. Navy on the eve of World War I. Such changes were inevitable given the tremendous impact of radio on warfare at sea and the significant operational advantages rapidly accruing to rivals abroad. But the transition was prolonged, and it relied heavily upon the determined efforts of a few key individuals willing to defy the service's prevailing cultural norms.[17] The operational penalty for delay might have been steep had the United States been confronted with a serious naval challenge prior to 1917.

Critics who had seen wireless reducing the authority of the commanding officer at sea have indeed proven correct. Command authority has migrated upward throughout the twentieth century as communications capabilities have expanded, most notably through the introduction of automated computer-to-computer tactical data exchanges among ships and aircraft in the 1960s and the introduction of long-range satellite communications in the 1970s. However,

because of the technical limitations on communications range, capacity, and reliability, the individual commanding officer's leadership has not, as some feared, been rendered "merely titular."[18] In fact, the commanding officer afloat has preserved most of the prerogatives and powers by which command authority at sea has traditionally been defined. However, when one looks ahead to the prospect of virtually unlimited movement of information made possible by emerging satellite communications systems, it does not appear that this traditional concept of command authority—either afloat and ashore—will continue to be immune from major change.

Organizing for Network Warfare

Information networks will potentially enable soldiers and seamen at the lowest levels to know as much as the most senior commanders about the combat situation throughout an entire theater of operations. They will know about lucrative enemy targets, potential threats to their own survival, and the location and status of their own forces and strike assets. "Joint Vision 2010" predicts that the result of this information networking will be a decentralization of command authority, with "individual warfighters . . . empowered as never before."[19] This view reflects an expectation that expanding information flows will enable command authority to migrate downward to the lowest echelons, offering unprecedented opportunities for initiative and independent operations by individuals and small units—what has been termed "decentralized empowerment."[20] Some envision the ultimate combat organization as a network of distributed systems with individual nodes exchanging information laterally and acting independently in pursuit of common system goals—an organization essentially freed from centralized authority altogether. This is undoubtedly (from a narrowly professional point of view) every warrior's ultimate desire—unlimited authority to apply unlimited lethality.

But are these organizational outcomes likely? Will emerging information technologies in fact reverse the trend toward centralization and relative reduction in command authority that has been proceeding since the introduction of wireless communications? Perhaps so, but several factors suggest that a more likely prospect is that of a very rapid movement toward even greater command centralization on the battlefield, accompanied by an unprecedented reduction in both individual and command authority.

Flattening the Command Hierarchy for Speed. The achievement of "bandwidth on demand" may represent final confirmation that the ability of machines to manipulate and move data has far outpaced individual human capacity to comprehend and act on that information. In the quest for increased speed of

operations through system networking, the human decision maker is likely to become conspicuous as the primary impediment to further progress.[21] Better filtering and display of information, along with better training, can mitigate somewhat the limitations of the human brain, but there seems to be a growing consensus that truly significant increases in system speed will require the removal of as many humans as possible from the decision-making process.[22]

One approach is to establish direct communications connectivity between senior headquarters and combat sensors or weapons—thus making the traditional pyramid-shaped command hierarchy "flat" by discarding the intervening echelons that have traditionally passed and filtered information between those who command and those who execute. Such a flat and highly centralized hierarchy, with troops in the field linked directly to the most senior headquarters element, characterized the combat organization of the Marine Corps' 1996 HUNTER WARRIOR Advanced Warfighting Experiment.[23] In that exercise, removal of the middle layers of command brought faster response and more efficient allocation of ordnance; but it also resulted in the physical removal of company and battalion officers and noncommissioned officers from command positions and their relocation to rear areas far from the battlefield—a significant change in the traditional concept of combat leadership.[24] Although perhaps not indicative of future Marine combat organizations, the HUNTER WARRIOR experience nevertheless suggests that networked combat certainly offers no promise of "empowerment" of company-grade officers.[25]

Automating Human Functions for Speed. A second approach to increasing the tempo of operations is through the expansion of machine automation of command functions—substituting computers for as many human decision makers as possible. Satellite communications have already made commonplace the automated exchange of tactical information between widely dispersed units. Emerging concepts like the Navy's Cooperative Engagement Capability (CEC) and the "Ring of Fire"—real-time networks of the sensors and weapons of ships, aircraft, and units ashore for integrated target engagement—hold out the prospect of future theater-wide architectures conducting operations "via a distributed, automatically self-configuring network."[26] Such systems will rely on computer algorithms rather than human planners to position the units in the network and to employ individual sensors and weapons of each. This may eventually lead to fully automated, joint force rules of engagement—one of the explicit goals of the proposed global system of systems architecture to support "Joint Vision 2010."[27] Thus in future combat situations, a networked computer rather than a human being may well be "deciding" where a unit is to locate itself, when it is to shoot, and at what. Moreover, the inherent logic of networks argues for systems without a designated central control point, and to the extent

that theoretical goal is achieved it may become unclear to individual commanding officers who or what is exercising authority over their units' operations and weapons at any given time.

Moving from Protracted Attrition Warfare to High-Speed Precision Warfare. Emerging information technologies are making possible increasingly "smart" weapons that can locate and strike specific targets over virtually unlimited ranges. The transition from a "dumb" to a "smart" arsenal has prompted efforts to shift in general from mass application of force against very large and indiscriminate target sets, to precise delivery against critical system nodes. The idea is to halt an invasion by destroying the critical bridge or fuel truck instead of trying to attack all of the enemy's armored vehicles, or to take down an air defense grid by striking the critical power transformer rather than many individual missile sites. Some even postulate that strategic leverage might be achieved by destroying the critical points that sustain a nation's political, military, and economic systems.[28] The conceptual goal is "one target, one weapon," against the smallest possible number of critical targets, so as to achieve the objective with minimal cost, risk, death, destruction, collateral damage, and ordnance expenditure.[29]

The expectation of a high probability of kill per weapon is a fundamental assumption behind the continued U.S. reliance on aircraft delivery of ordnance, with its associated low salvo rates, rather than movement toward a large arsenal of fully autonomous, long-range missiles.[30] But this deprecation of attrition warfare, using large numbers of cheap weapons, in favor of precision warfare reliant upon a much smaller number of very accurate but comparatively expensive weapons will also mean a rapidly decreasing tolerance for ordnance expenditure that achieves no effect.[31] Ordnance conservation will likely be a major consideration for a commander who must also plan for unidentified future contingencies, which might arise quite rapidly and have far more strategic importance than the present conflict. Thus as individual troops may be increasingly empowered with information on enemy targets and own force assets, they may be denied the "ordnance on demand" needed to act on that knowledge—because the selection of targets must be reserved to higher authority.[32]

The result is likely to be a highly centralized planning *and* execution process like that evident in HUNTER WARRIOR, where individual field troops were essentially reduced to passive battlefield sensors directly supporting a single ordnance-allocation authority. Recent war games have surfaced the possibility that relative ordnance scarcity may oblige future theater commanders to withhold authority from local commanding officers even to expend their own weapons in unit self-defense—surely one of the most jealously guarded prerogatives of "command."[33]

Automating for Efficiency. Speed of command and ever-increasing force precision are not the only goals likely to drive command centralization and the loss of authority on the battlefield. In addition, the quest for reduction in military operating costs is stimulating efforts to increase systems reliability in order to reduce equipment downtime and maintenance expenses. There are proposals to exploit increasing bandwidth to create real-time logistics reporting networks. These would use microsensors embedded in key equipment components to provide continuous and automatic status reports directly to distant, senior maintenance authorities and also the civilian manufacturers of the equipment. The idea is that such rapid, automated data will improve reliability through real-time operational-performance analysis, greatly reduce the time required for repair by automating the process of obtaining spare parts and technical assistance, and eventually reduce the number of uniformed personnel devoted to forward maintenance and repair. However, an automated reporting network would also tell remote authorities as much if not more about a unit's material status than the commanding officer knows him or herself. It would eventually allow the automated generation of unit equipment casualty reports, at which point distant commanders will have effectively assumed the authority of on-scene commanding officers for determining a unit's operational and material readiness.

Knowledge Enables Control. It was the inability of leaders at geographically distant command posts (to which they were obliged to withdraw when armies and fleets grew too large to lead personally in combat) that originally demanded delegation of both command authority and responsibility to junior subordinates. In the future, however, information technologies may allow senior commanders to know much more about distant situations—perhaps even more than those on the scene, thanks to multisource information fusion. There is no reason to expect that they will be able or willing to avoid involving themselves in actions taken by their subordinates, of whose circumstances they will believe they have full knowledge.

Today the assumption of direct control over lower-echelon activity is commonly derided as unwarranted "dabbl[ing] in . . . subordinates' business."[34] Some contemporary junior officers express fear that better information will tempt senior commanders to "interfere in lower-echelon decisions," leading to situations that will "compromise initiative and undermine the effectiveness of command" and violate a "principal tenet of command."[35] But in fact decentralization of execution may simply be an artifact of pre-network, low-data-rate operations. The likelihood that greater experience and knowledge will reside at higher command echelons would seem to argue for centralizing decision making and control to the fullest extent allowed by communications capacity.[36]

Moreover, future knowledge-empowered commanders are likely to find it ethically unacceptable to absolve themselves of accountability for lower-level actions of which they have full knowledge and control, and for which they are ultimately responsible.

There may be still other cultural impacts of organizational changes to exploit information technologies. For example, as networks extend themselves over greater spatial expanses they will undoubtedly reach across the boundaries that have traditionally separated ground, sea, and air environments. System function will likely become more important than service affiliation, blurring the distinction between Army, Navy, Air Force, and Marine Corps authority on the battlefield. Also, the transition from platform-centric to network-centric warfare suggests to some the emergence of an entirely new warfare area—and thus a need to create new network warfare management specialties on a par with those of armor, aviation, submarines, etc. If so, it will mean entirely new criteria for both promotion and command, affecting a large group of officers. Without an increase in the number of officers in the senior ranks, many of those in traditional warfare areas may find themselves increasingly uncompetitive for promotion and command opportunity as a result of then-promising career choices made years before.[37]

Preparing for a Different Future

Certainly, future technological realities may fall far short of current expectations. Despite today's apparent trends, transmission bandwidth and automated data processing capacities may never catch up with network demand, and increasing dependence upon satellites—especially commercial communications satellites—may be seen as an unacceptable wartime vulnerability. Nevertheless, the U.S. military's embrace of network warfare as a primary goal for the future begs a commensurate effort to understand its organizational and cultural implications. Historically, organizational changes of the magnitude suggested by the now-emerging information technologies have taken decades to implement—time for a new generation of officers less wedded to existing cultural norms to rise to positions of leadership within the military services.[38] If the level of organizational change suggested by network warfare is in the best interest of the U.S. military, then it would be wise to institutionalize processes that allow the commensurate cultural change to proceed at a rate that keeps pace with advancing technology.

The most important institutional initiatives will probably be those that stimulate as many officers as possible to think about different operational and organizational concepts, and that accustom the broad society of officers in all

services to the likelihood that their profession will undergo major changes during the courses of their own careers. The service and joint war colleges may be best positioned to take on this challenge, through their core curricula and directed research.[39] These institutions have a unique opportunity to capture most of the best junior and senior officers and offer them both the intellectual stimulation and the time to think seriously and critically about different kinds of future military organizations and service cultures.

Perhaps the most important reason for stimulating serious thinking about the prospect of major change is that doing so will help determine whether current future-warfare goals are in fact to the relative advantage of the U.S. military over the long run. There has been speculation, but little open debate, about possible risks associated with network warfare, and specifically whether an ever-increasing tempo of operations may perhaps be fraught with more operational peril than benefit for the United States.[40] An equally important question is whether the cultural changes that seem to be required to exploit future information technologies will actually prove to be so detrimental to the ethos necessary to a successful military organization as to offset any operational advantages. Alfred Thayer Mahan originally opposed the construction of dreadnought-type battleships for the U.S. fleet because he feared that having only long-range guns would foster in the U.S. sailor an "indisposition to close" with the enemy, thus undermining the courage of the naval commander. As Elting Morison observed, the long-range battle did not cause sailors to lose their bravery but rather to "reveal their bravery in a different way."[41] However, Mahan's concern should not be too readily dismissed as we ponder our future technological options. It is possible that emerging information technology may indeed allow military leadership to become too remote, too automated, and too detached—and for military organizations to become too diffuse to maintain the unit cohesion necessary to stand in conditions of prolonged combat and severe hardship. These may be the issues most deserving of our careful consideration, before rapidly evolving technologies draw us too far down the path of organizational and cultural change.

Notes

1. The past several years have witnessed truly significant increases in satellite bandwidth available to major afloat platforms through expanded use of leased commercial satellites. Programs like CHALLENGE ATHENA and GBS (Global Broadcast Service) have increased the send and receive capacities for aircraft carriers and command ships from thousands of bits per second to millions. The expanding number of commercial satellites, coupled with continued reduction in antenna size, is expected to make such communications capacities available to ever-smaller units both afloat and ashore. There is at least the possibility that transmit/receive capacities will exceed both commercial and military demand in the foreseeable future (admittedly a long-promised but yet-to-be-achieved goal).

2. See for example, William A. Owens [Adm., USN], "The Emerging System of Systems," U.S. Naval Institute *Proceedings* (May 1995), and Arthur K. Cebrowski [VAdm., USN] and John J. Garstka, "Network-Centric Warfare: Its Origin and Future," U.S. Naval Institute *Proceedings*, January 1998, pp. 28–35.

3. William S. Cohen, *Report of the Quadrennial Defense Review* (Washington, D.C.: May 1997), pp. 39–40, 42–3; "Joint Vision 2010" (Washington, D.C.: Office of the Chairman of the Joint Chiefs of Staff, July 1996), p. 21; and Cebrowski.

4. Cebrowski.

5. Ibid., p. 32.

6. See for example Emmett Paige, Jr. (Assistant Secretary of Defense [Command, Control, Communications, and Intelligence]), "Achieving the Integrated Systems Concept," address at the Armed Forces Communications and Electronics Association (AFCEA) International Technet '96 Convention, 4 June 1996 (published in *Defense Issues*, vol. 11, no. 51); Joseph S. Nye and William A. Owens, "America's Information Edge," *Foreign Affairs* (March/April 1996), pp. 20–36; and Cebrowski, p. 32.

7. Elting E. Morison, *Men, Machines, and Modern Times* (Cambridge, Mass.: MIT Press, 1966), pp. 17–44.

8. Although the adoption of wireless affected all service cultures, the experience of the Navy is emphasized here because wireless equipment proved practical for ship installation long before it could be widely utilized by mobile ground vehicles or by aircraft. Moreover, the subsequent diminution of command authority brought about by wireless appears to have been much more marked in the Navy than the other services. Today, however, the reduction in size of equipment and power sources suggests that future information systems are not likely to favor shipboard introduction over ground and air platforms.

9. This exception was Howe's victory of the Glorious First of June in 1794, which took place about five hundred miles west of Brest, France. See Karl Lautenschlager, "Technology and the Evolution of Naval Warfare," *International Security* (Fall 1983), p. 13.

10. In 1911 the U.S. Navy was still using only one frequency for transmission and reception. By contrast the Royal Navy had been using eight or more frequencies since 1907, the Germans four, and the Japanese and Italians three. Arthur Hezlet, *Electronics and Sea Power* (New York: Stein and Day, 1975), p. 75.

11. For instance, Commander Bradley Fiske, one of the Navy's foremost technical authorities, asked whether "the very convenience of [radio's] use in peace betray us into the pernicious habit of handling our warfleet in peace by a means that would prove worthless in war?" Bradley A. Fiske, "War Signals," *Proceedings* of the U.S. Naval Institute (December 1903), p. 932.

12. Susan J. Douglas, "Technological Innovation and Organizational Change: The Navy's Adoption of Radio, 1899–1919," in *Military Enterprise and Technological Change*, ed. Merritt Roe Smith (Cambridge, Mass.: MIT Press, 1985).

13. The concept of the line as the "corps of command" was a common theme of traditionalists during the acrimonious amalgamation of the line and the staff engineers, which was in progress when wireless arrived in the fleet. See, for example, "Navy Line and Staff," *Army and Navy Journal*, 3 October 1896, p. 69. The organizational demands of radio presented the second major cultural challenge to the line within a generation.

14. "Wireless Control of the Fleets," *Army and Navy Journal*, 9 May 1908, p. 965.

15. Ibid.

16. Hezlet, p. 66.

17. Studies of innovation in the military indicate a common pattern for these key individuals: junior officers willing to promote seemingly radical ideas even at the risk of their professional careers, coupled with senior officers who promote the innovations and protect the innovators. See Vincent Davis, *The Politics of Innovation: Patterns of Navy Cases* (Denver, Colo.: Univ. of Denver Press, 1966–1967); and Stephen Peter Rosen, *Winning the Next War: Innovation and the Modern Military* (Ithaca, N.Y.: Cornell Univ. Press, 1991). The impetus for effective wireless organization in the U.S. fleet resulted largely from the fortunate pairing of Lieutenant Stanford C. Hooper (the so-called "father of naval radio") with Rear Admiral Charles J. Badger (then commander in chief of the Atlantic Fleet). See Douglas, pp. 155–65.

18. Douglas, p. 148. Until quite recently, ships at sea were primarily dependent upon 75 baud, hundred-word-per-minute high-frequency circuits for long-range communications. The arrival of satellite communication in the 1970s greatly increased wireless range and reliability and capacity, but bandwidth available to individual ships still remains short of the growing demand.

19. "Joint Vision 2010," p. 13.

20. Director of Command, Control, Communications, and Computers (Joint Staff) and Director, Defense Research and Engineering (Office of the Secretary of Defense), *Advanced Battlespace Information System (ABIS) Task Force Report: Executive Summary* (Washington, D.C.: May 1996).

21. It is not clear what level of operational tempo will be considered "fast enough," but stated goals envision expected changes of orders of magnitude. For instance, a senior Defense official called for an intelligence process that would deliver "real-time targeting to weapons systems in seconds (not hours)" (Paul G. Kaminski, Under Secretary of Defense for Acquisition and Technology, "Enabling Intelligence Technologies for the 21st Century," Statement before the House Permanent Select Committee on Intelligence, 18 October 1995). The former Chief of Staff of the Air Force has spoken of future air power perhaps being able

to "engage 1500 targets within . . . the first *minutes* of a conflict" (Ronald R. Fogleman [Gen. USAF], "Air and Space Power in the 21st Century," Ira C. Eaker Lecture, U.S. Air Force Academy, 6 April 1995). The Navy's Director for Space, Information Warfare, Command and Control (N6) has articulated a requirement that the Navy be able to deliver supporting fires to the Marines in "about two minutes" (Richard Lardner, "Cebrowski Urges Shift to 'Network Centric Warfare,'" *Defense Information and Electronics Report*, 20 June 1997).

22. Of course another option is artificial human-performance enhancement. Various pharmacological, enzymatic, and genetic approaches have been proposed to achieve such goals as increased human resistance to information overload, modification of the sleep-wake cycle, extension of the period of maximum human performance, and direct machine control by neural impulses. However, uncertainties associated with human response to such efforts, coupled with ethical qualms within the United States about manipulating the human brain, make these unlikely options for the U.S. military.

23. HUNTER WARRIOR culminated the first phase of the Marine Corps's five-year "Sea Dragoo" program.

24. An observer noted that the company-grade officers affected were "greatly disturbed" by this change. Jon R. Anderson, "Praise & Contempt," *Navy Times*, 18 August 1997.

25. A recent series of Navy war games exploring combat organizational structures in the year 2020 suggests that future commanders may demand that organizations be very flexible, with a capacity to be either flat or hierarchical, centralized or decentralized, depending upon the specific situation. For example, the game players revealed a preference for decentralization of authority during peacetime operations (including military operations other than war) but for centralized command in combat. Moreover, players favored a two-tier arrangement during wartime, with "local commanders . . . given defensive freedom of action, while offensive operations remained tightly regulated, specified, and directed." See Edward S. Smith, Jr. [Capt., USN], "The Navy RMA War Game Series: April 1995–November 1996," *Naval War College Review*, Autumn 1997, p. 28.

26. Dean Barsaleau, "CEC: The Unprecedented Force Multiplier," *Surface Warfare* (September/October 1994), p. 26. CEC is an area air-defense concept linking sea, shore, and air-based sensors and weapons in a common network. "Ring of Fire" is a surface fire-support concept tested during fleet battle experiments in 1997; it features automated integration of multiple fire-support assets into a common network.

27. *ABIS Task Force Report: Executive Summary.*

28. See, for example, John A. Warden [Col., USAF], "The Enemy as a System," in Air Command and Staff College, *Concepts in Airpower for the Campaign Planner* (Maxwell AFB, Ala.: 1993), pp. 5–27. U.S. doctrine does not yet embrace "nodal" warfare but does hold the application of "precise force to achieve the desired effects" as its conceptual goal. See Commander, Joint Warfighting Center, *Concepts for Future Joint Operations: Expanding Joint Vision 2010* (Fort Monroe, Va.: May 1997), p. 52.

29. Kaminski, p. 2; and *Concepts for Future Joint Operations*.

30. The United States is building up to a planned inventory of more than three hundred thousand precision guided munitions; however, only a few thousand of these will not be dependent upon aircraft delivery (U.S. General Accounting Office, *Weapons Acquisition: Precision Guided Munitions in Inventory, Production, and Development* [Washington, D.C.: June 1995]).

31. The average cost of each of the more than two hundred thousand general-purpose bombs dropped in Operation DESERT STORM was about $2,000, compared with more than $1.1 million each for the 333 sea and air-delivered cruise missiles that were expended (Office of the Secretary of the Air Force, *Gulf War Air Power Survey*, vol. 5 [Washington, D.C.: 1993], p. 581). There are plans to produce lower-cost long-range ordnance, but individual stand-off and long-range missiles will still be priced in the neighborhood of from $500,000 to $750,000 each.

32. This resource-demand mismatch has long been characteristic of the Navy's Composite Warfare Commander (CWC) organization, introduced in the early 1980s to enable a more rapid command cycle through distributed decision making. In practice, a multithreat environment commonly so accelerates demand for scarce assets that resource allocation decisions—especially for multipurpose ships and aircraft—are routinely elevated to the battle group commander.

33. In a 1995 Joint Staff–sponsored war game, a centralized theater commander saw his resource deficiency as so acute that he assumed the authority to determine when his subordinate ship commanders could fire long-range surface-to-air missiles in self-defense. Reminiscent of the early days of wireless, one Aegis "commanding officer" openly threatened to withdraw his unit from the theater-wide defense network if his prerogative to fire in self-defense were taken away.

34. Eliot A. Cohen, "A Revolution in Warfare," *Foreign Affairs* (March/April 1996), p. 50.

35. Jeffrey A. Harley [LCdr., USN], "Information, Technology, and the Center of Gravity," *Naval War College Review*, Winter 1997, pp. 83–4.

36. However, the migration of battlefield decision-making authority to ever higher echelons raises the critical question of how the military is to create competent senior battlefield leaders in the future if junior

officers are trained to expect and rely on continuous direction from above. An expanded use of realistic battlefield simulations for officer training may be one approach.

37. Some have proposed the creation of a dedicated "information corps"; see, for example, Martin C. Libicki and James A. Hazlett, "Do We Need an Information Corps?" *Joint Force Quarterly*, Autumn 1993. But critics have pointed out that it may make no more sense to establish an information corps today than it would have to create an "internal combustion corps" at the turn of the century. New career paths and specialties then arose around applications of this engine technology—for example, armor and aviation—rather than the power plant itself. The U.S. Navy's exploitation of wireless depended heavily on the creation of the radio officer billet on afloat platforms in 1912 (Douglas, p. 159) and recognition of that billet by senior officers as career enhancing. The radio officer, however, was created within the existing warfare specialties, not as a new warfare area. Nevertheless, continued exploration of a separate network warfare specialty on a par with the existing platform-centered ones needs to be part of an innovation process.

38. This is evident in Susan Douglas's study of the Navy's exploitation of wireless and is an explicit conclusion of Stephen Rosen's noteworthy analysis of military innovation (*Winning the Next War*).

39. The idea of continuous military innovation and periodic "revolutions in military affairs," although seemingly well grounded in history, is not institutionalized in either the curricula or research efforts of any of the war colleges. While these institutions seem to have served as something of a breeding ground for innovative thinkers during the interwar period, some critics argue that the war colleges have since taken on the role of preservers of the status quo rather than agents of innovation and change.

40. See, for example, James R. FitzSimonds, "The Coming Military Revolution: Opportunities and Risks," *Parameters*, Summer 1995, pp. 30–6.

41. Morison, p. 35.

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